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NIRSpec Technical Note
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Preliminary report on the instability of channel drift in FPA104

Version 2.0 Feb 2014 – added FM2-B observations

1 INTRODUCTION

The NIRSpec FPA104 installed in NIRSpec during the first two cryo test campaigns (FM1 and FM2) at IABG in 2011 and 2013 shows variations in the channel drift defined as the change of ADU from the start of a frame and the end of a frame within an output channel (Fig 1). In this document we summarize the observational evidence of this variation, the correlation with the telemetry reading of the DSUB bias detector current and propose a way forward for the full investigation of this issue.

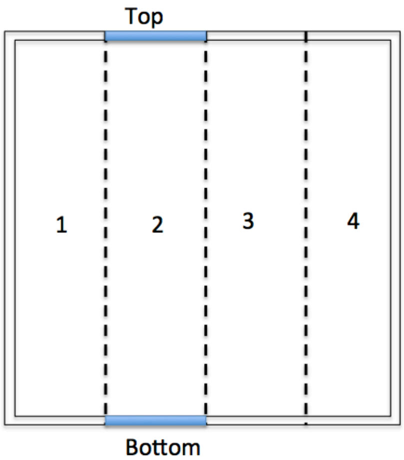

Figure 1. Definition of channel drift calculated as the difference between the mean ADU level in the top and bottom reference pixels in each output. The outputs are here simply defined with numbers from 1 to 4 instead of their correct readout channels (7,15,23,31)

2 SUMMARY OF OBSERVATIONAL EVIDENCES:

- The change in channel drift is seen in data acquired at both FM1 and FM2A although it was more frequent in FM1 than in FM2A.
- There is no evidence of this effect in data acquired at DCL during the characterization of FPA104.
- This change in channel drift, when occurs, is present in both SCAs.
- The change in channel drift impacts mostly output #1.
- Data show a dual drift mode, however these modes are different between FM1 and FM2. During FM1 the most frequent drift mode was very similar to the one observed in data acquired at DCL. During FM2A the most frequent drift mode was the secondary mode observed during FM1. This difference is mostly due to the different version of the ASIC μcode used for the two different test : version 5.3 for FM1 and 6.0 for FM2
- The changes in drift are associated with change in readout mode (full frame/window mode). However a change in readout mode does not necessarily induce a change in drift.
- Since top and bottom reference pixels are only available in full frame mode we cannot assess the drift during window mode exposures.
- We have found a clear correlation between the change in the channel drift and telemetry readings of the DSUB bias current. We are however aware that the ASIC telemetry values are potentially not reliable due to a known issues with the version of ASIC FAC used during the cryo campaigns.

3 IMPACT ON DATA

The impact on data is most evident in dark exposures. During FM2A a change in drift never impacted dark exposures. We will therefore show the effect on FM1 data.
Figure 2 shows a difference of two dark exposures taken in similar drift conditions; one acquired at DCL during the FPA104 characterization and one at IABG during FM1. The known “frame” features are visible due to small changes in the operating temperature between the two tests. There are, however, no strong signs of output dependent residuals.

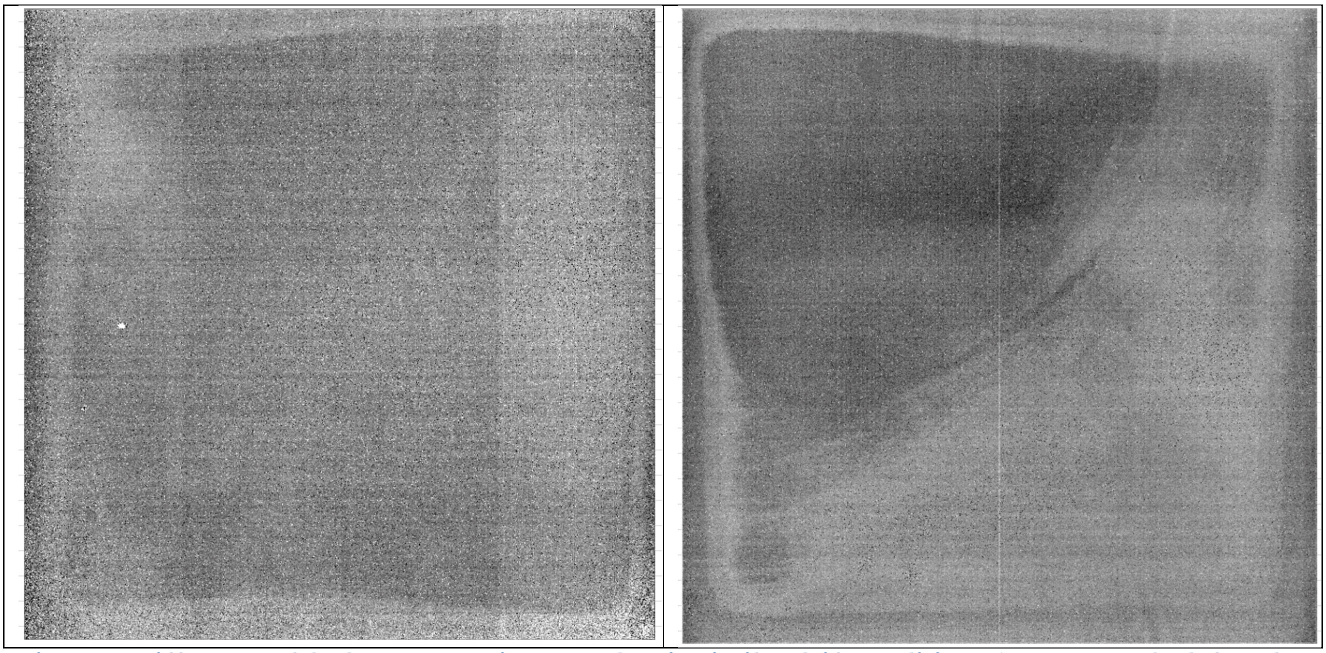

Figure 2. Difference of dark count rate images taken in similar drift conditions (SCA491 on the left and SCA492 on the right). [DCL and FM1 data]

Figure 3 shows instead the difference between the same dark exposure taken at DCL, and used for Figure 2, and one FM1 exposure with a different channel drift. The "frame" features are still visible (due to the same temperature change) but the main characteristic is a marked difference in the output #1.

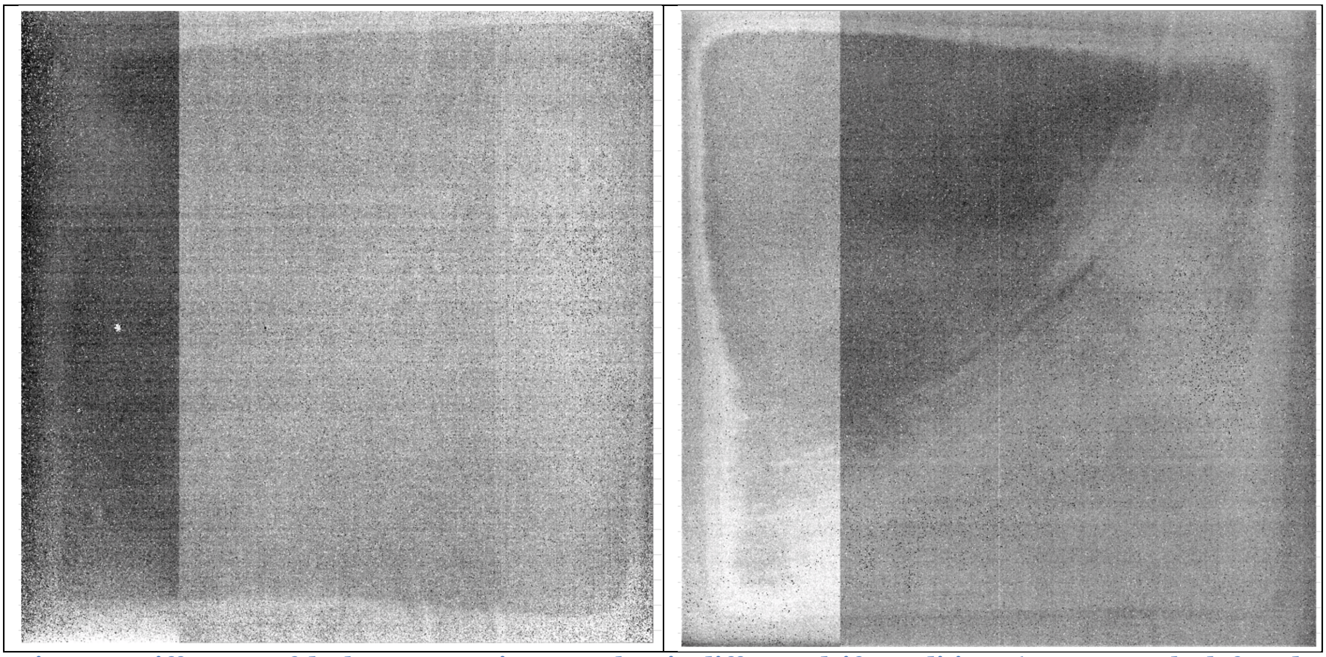

Figure 3. Difference of dark count rate images taken in different drift conditions (SCA491 on the left and SCA492 on the right). [DCL and FM1 data]

Investigation of the signal in the reference pixel area of the effected exposures confirms quantitatively that the channel drift changes mainly in output one. Figure 4 show the channel drift in a sequence of 177 exposures acquired on Jan 19 2013 during FM2. Each symbol represents the measurement for a full frame exposure. The NID in the horizontal axis indicates the unique ID number that identifies an exposure. Each output is plotted with a different colour. Red for output#1, green for output #2, blue for output #3 and black for output#4. Full and empty circles represent the mean drift measured in even and odd column respectively.

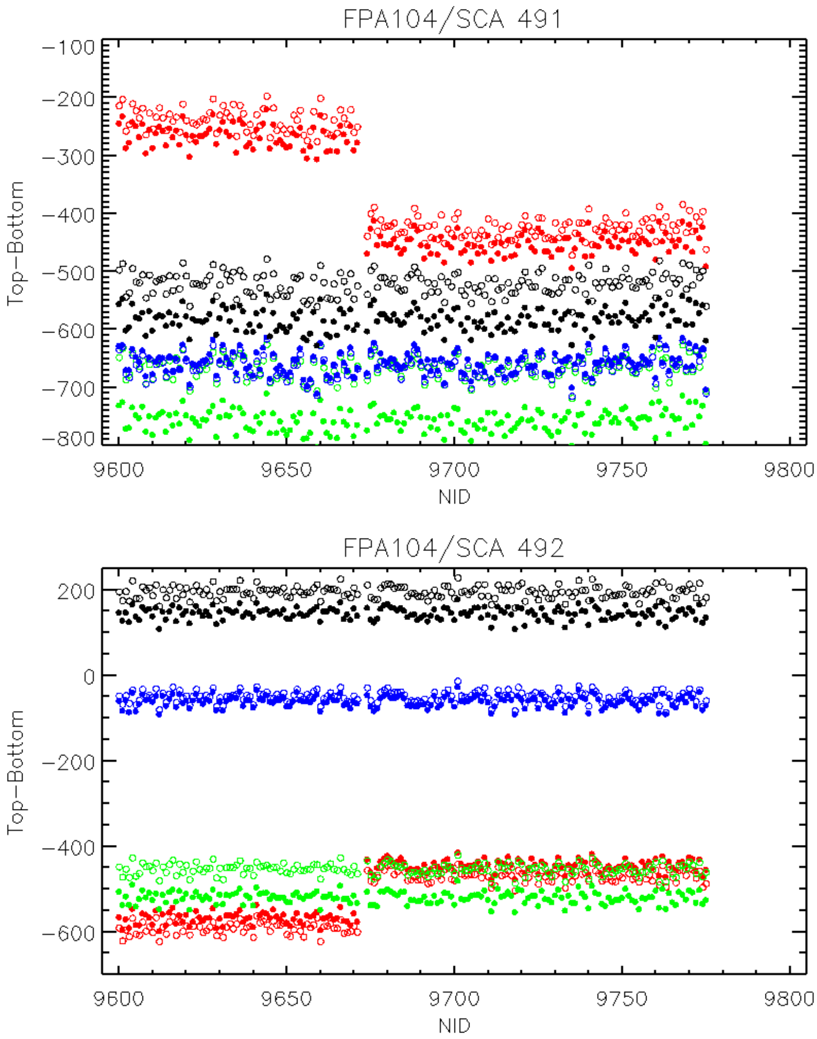

Figure 4. Channel drift in a subset of exposures acquired during FM2A for SCA491 (top) and SCA492 (bottom). See text for a description of the colours and symbols.

Both SCAs show a change of drift for output #1 (red). The break corresponds to two window exposures with NID=9672 and 9673 which do not have a corresponding symbol in the figure since we do not have reference pixels in window mode data.

The statistics for all full frame data taken during FM2A is provided in table 1 and 2 for SCA491 and SCA492, respectively. In all NIRSpec SCA even and odd columns can show differences up to several hundred ADUs. We therefore provide the statistics for both separately. FM2 data show two channel drift states. The difference between the two states is up to 185 ADUs for output #1 of SCA491 and 123 ADUs for output #1 of SCA492. It should be noted that the sign of the difference is opposite between SCA491 and SCA492. All other outputs show drift changes below 3 ADUs.

Table 1. Statistics of the reference pixel level separated for output and even/odd columns in the two states for SCA491 during FM2A. The panel at the bottom show the change in the drift calculated as drift in state-1 minus drift in state-2. The column marked with EOD list the difference between even and odd columns.

FPA104/SCA 491													
	STATE -1												
		Output 1			Output 2			Output 3			Output 4		
		even cols	*odd cols*	EOD	*even cols*	*odd cols*	EOD	*even cols*	*odd cols*	EOD	*even cols*	*odd cols*	EOD
	Top Ref Pix	16041.4	16047.5	-6.1	15369.4	14999.3	370.1	16402.4	15754.5	647.9	14994.8	14947.8	47
	Bottom Ref Pix	16308.3	16286.5	21.8	16127.7	15666.6	461.1	17060.6	16418.9	641.7	15579.4	15469.6	109.8
	Drift	-266.9	-239		-758.3	-667.3		-658.2	-664.4		-584.6	-521.8	
	STATE -2												
		Output 1			Output 2			Output 3			Output 4		
		even cols	*odd cols*	EOD	*even cols*	*odd cols*	EOD	*even cols*	*odd cols*	EOD	*even cols*	*odd cols*	EOD
	Top Ref Pix	15853.9	15858.1	-4.2	15362.6	14993.2	369.4	16405.2	15757.2	648	14994.7	14939.8	54.9
	Bottom Ref Pix	16306.2	16283	23.2	16119.4	15658.7	460.7	17061.7	16420.2	641.5	15576.7	15460.2	116.5
	Drift	-452.3	-424.9		-756.8	-665.5		-656.5	-663		-582	-520.4	
		Output 1			Output 2			Output 3			Output 4		
	Delta Drift	*even cols*	*odd cols*		*even cols*	*odd cols*		*even cols*	*odd cols*		*even cols*	*odd cols*	
		-185.4	-185.9		1.5	1.8		1.7	1.4		2.6	1.4	

Table 2. Statistics of the reference pixel level separated for output and even/odd columns in the two states for SCA492 during FM2A. The panel at the bottom show the change in the drift calculated as drift in state-1 minus drift in state-2. The column marked with EOD list the difference between even and odd columns.

FPA104/SCA 492

STATE -1												
	Output 1			**Output 2**			**Output 3**			**Output 4**		
	even cols	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**
Top Ref Pix	11613.9	11210	404	10475	10513.1	-38.1	11195.2	11672.7	-477.5	11900.5	12321.2	-420.7
Bottom Ref Pix	12183.3	11801.4	382	10994.6	10965.9	28.7	11256.2	11722.2	-466	11755.4	12125.4	-370
Drift	-569.4	-591.4		-519.6	-452.8		-61	-49.5		145.1	195.8	
STATE -2												
	Output 1			**Output 2**			**Output 3**			**Output 4**		
	even cols	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**	***even cols***	***odd cols***	**EOD**
Top Ref Pix	11697.2	11291.8	405	10468.3	10507.2	-38.9	11190.1	11663.6	-473.5	11892.1	12315.7	-423.6
Bottom Ref Pix	12143.3	11760.6	383	10989.6	10961.8	27.8	11252.1	11714.2	-462.1	11748.7	12121	-372.3
Drift	-446.1	-468.8		-521.3	-454.6		-62	-50.6		143.4	194.7	
	Output 1			**Output 2**			**Output 3**			**Output 4**		
Delta Drift	***even cols***	***odd cols***		***even cols***	***odd cols***		***even cols***	***odd cols***		***even cols***	***odd cols***	
	123.3	122.6		-1.7	-1.8		-1	-1.1		-1.7	-1.1	

4 CORRELATION WITH TELEMETRY

We have found that the change in drift correlates with the telemetry reading of the DSUB bias detector current. It should be noted that the ASIC FAC used during FM1 and FM2 does not reliably report telemetry readings. The values reported and shown below may be meaningless however they are indicative of a clear correlation between a SCA or ASIC state and the impact we see on the data.

The telemetry mnemonics that track the DSUB bias voltage are INRSD_A1_DSUB_V and INRSD_A1_DSUB_I respectively for the voltage and current of ASIC#1. Analogue mnemonics are available for ASIC#2. Figure 5 shows the value of the DSUB current as reported in the telemetry during the acquisition of the set of exposures shown in figure 4. For each exposure we plot the average of the DSUB current readings recorded in the comma separated value .csv file included in each exposure directory. All the red dots correspond to full frame exposures. The two blue dots in the centre of the range identify the two window mode exposures with NID=9672 and 9673. The DSUB current shows a dual mode. The switch in the DSUB bias current matches the change in drift shown in figure 4.

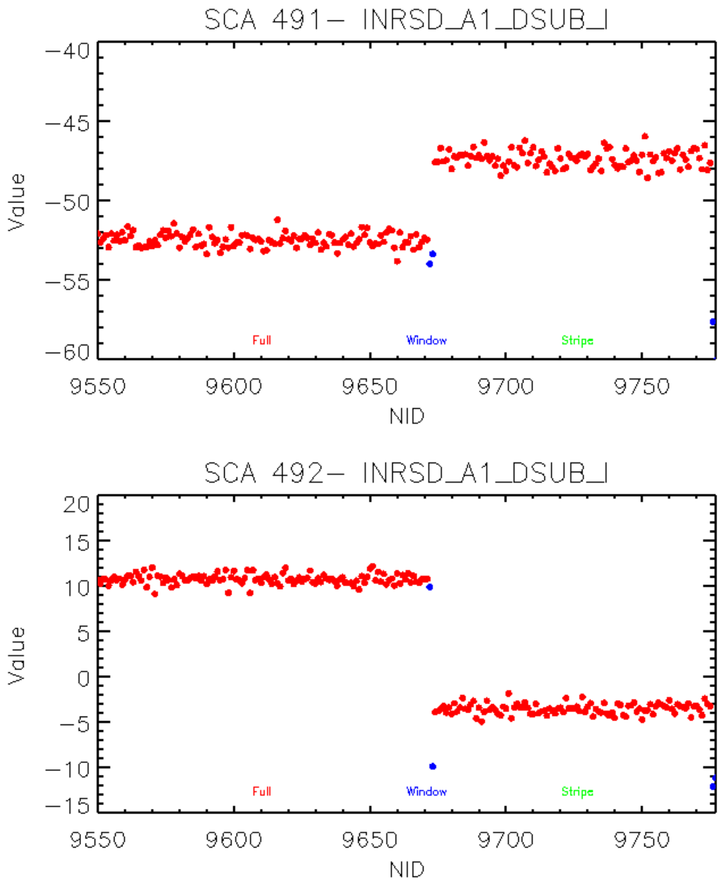

Figure 5 Reading of the DSUB bias voltage current during the exposures used for Figure 4. The jump after the two window exposures (blue circles) matches the change in drift shown in figure 4.

Figure 6 shows the correlation between the channel drift in all outputs and the variation in the readings of DSUB current telemetry. Each output is identified by a different colour. Red for output#1, green for output #2, blue for output #3 and black for output#4. Full and empty circles represent the mean drift measured in even columns and odd column respectively.

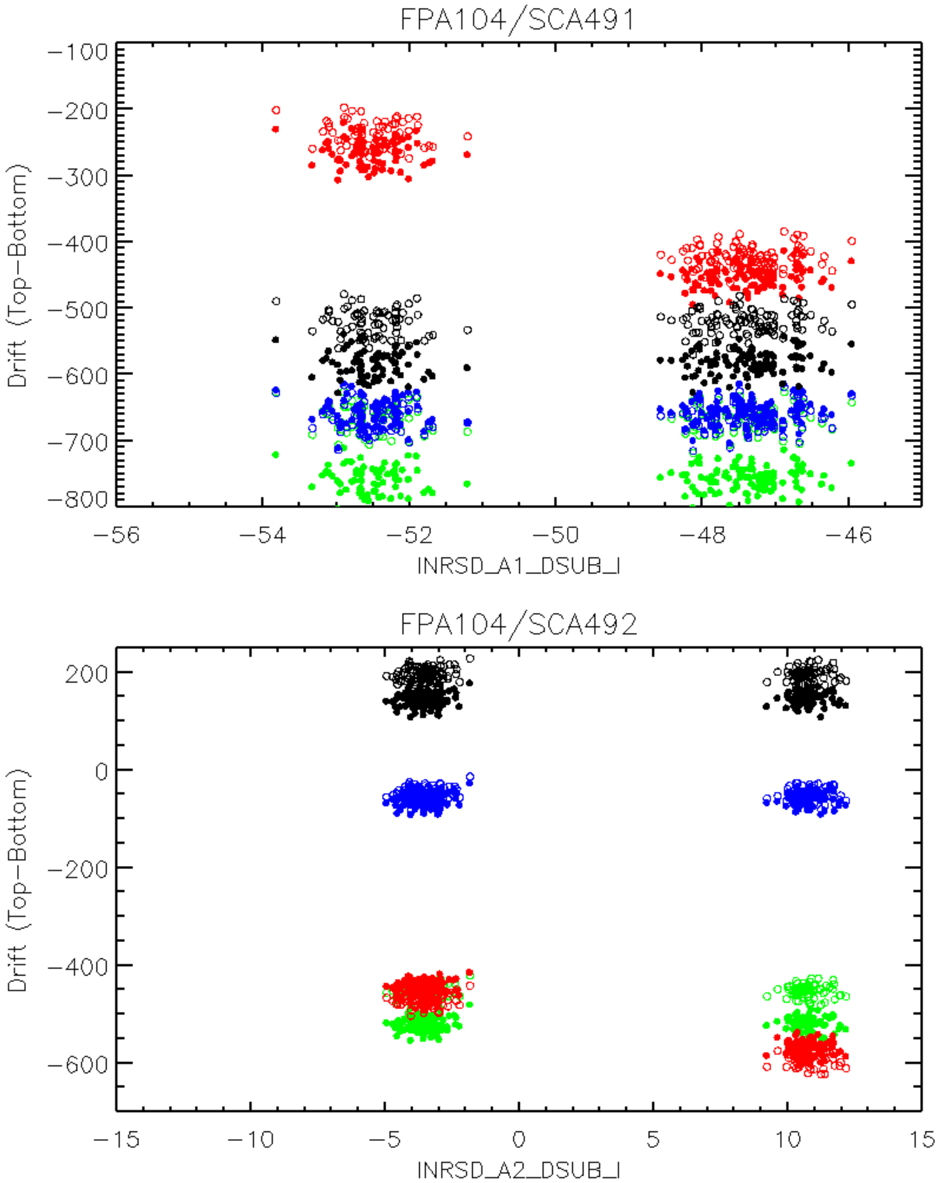

Figure 6 correlation between DSUB current reading and measured channel drift for a subset of exposures taken during Fm2. (see the text for colour and symbol explanation)

Due to this clear correlation it easy to identify when the change of readout mode induces a change in the channel drift. Figure 7 through 9 show the reading of the DSUB bias current during FM1, FM2-A and FM2-B respectively. Red circles represent full frame exposures; blue circles window mode exposures and green circles stripe mode exposures. For window mode exposures the reported value is, most of the time, not indicative of the status of the DSUB current during the exposure. The reading of the telemetry keyword is in fact done on a fixed frequency and as consequence the numbers of readings associated to an exposure depends on the exposure time. For window mode exposures the exposure time is usually

very short and therefore there are often very few readings of the telemetry. Moreover, since the .csv telemetry files includes telemetry from few seconds before the start of an exposure to few seconds after the end of the exposure it is possible that for very short exposures the values stored in the file do not provide information during the actual exposure acquisition. This explains the large scatter seen in the blue points. For longer exposures (red and green points) the scatter is significantly lower. Each jump in the DSUB current between the two states (and the related change in channel drift) occurs after a window mode exposure (a blue point). The only exception is the very first jump (NID =4185) occurred on Feb 03 2011 during the first phase of FM1 and it which is associate to a reboot of the SITS to recover from a space wire crash.
Figures 7-9 also show that the most common DSUB or channel drift state is inverted between FM1 (ASIC μcode 5.3) and FM2-A (ASIC μcode 6.0) and that during FM2-A the changes of state occurred less frequently.
During FM1 21% of the almost 1800 full frame exposure were acquired in an "anomalous" or secondary DSUB/channel drift state. During FM2 only 6% of the almost 4600 full frame exposure were acquired in an "anomalous" state.

At the beginning of FM2-B version 7 of the ASIC μcode was uploaded in the Detector System (DS). The ASIC personality files initially uploaded were not tuned for the new version of the μcode and the performance of the detector were not in line with those measured during FM2A with version 6 of the μcode. NTN-2013-015 describes the different adjustments done at the DS configuration in terms of μcode version and personality file in different phases of the FM2-B campaign. Figure 9 shows that in the initial phase, with version 7 and incorrect personality files the DSUB current was slowly decreasing with time and that it stabilized only after more appropriate personality files were uploaded (phase 2 in NTN-2013-015, transition indicated with a black vertical line in Figure 9).
As already noted between FM1 and FM2-A when two different versions of the ASIC μcode were used, the DSUB current values with version 7 of the ASIC μcode are different than with version 6. When the configuration of the DS system was reverted back to version 6 for the acquisition of the bulk of the data (middle region in Figure 9) the DSUB values were in line with those observed during FM2-A. During the six days of FM2-B no jump in the DSUB current were observed.

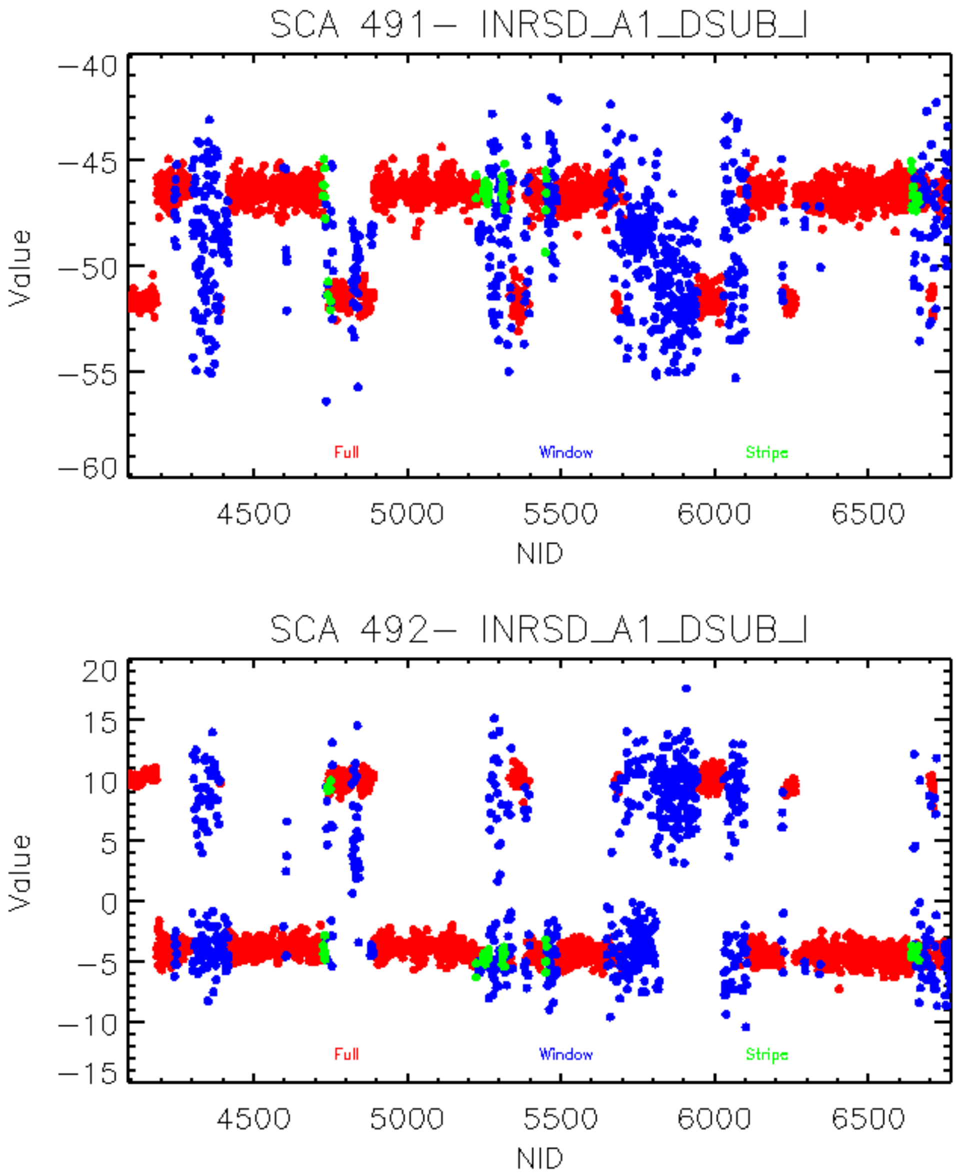

Figure 7 DSUB bias current telemetry reading during FM1 for SCA491 (top) and SCA492(bottom)

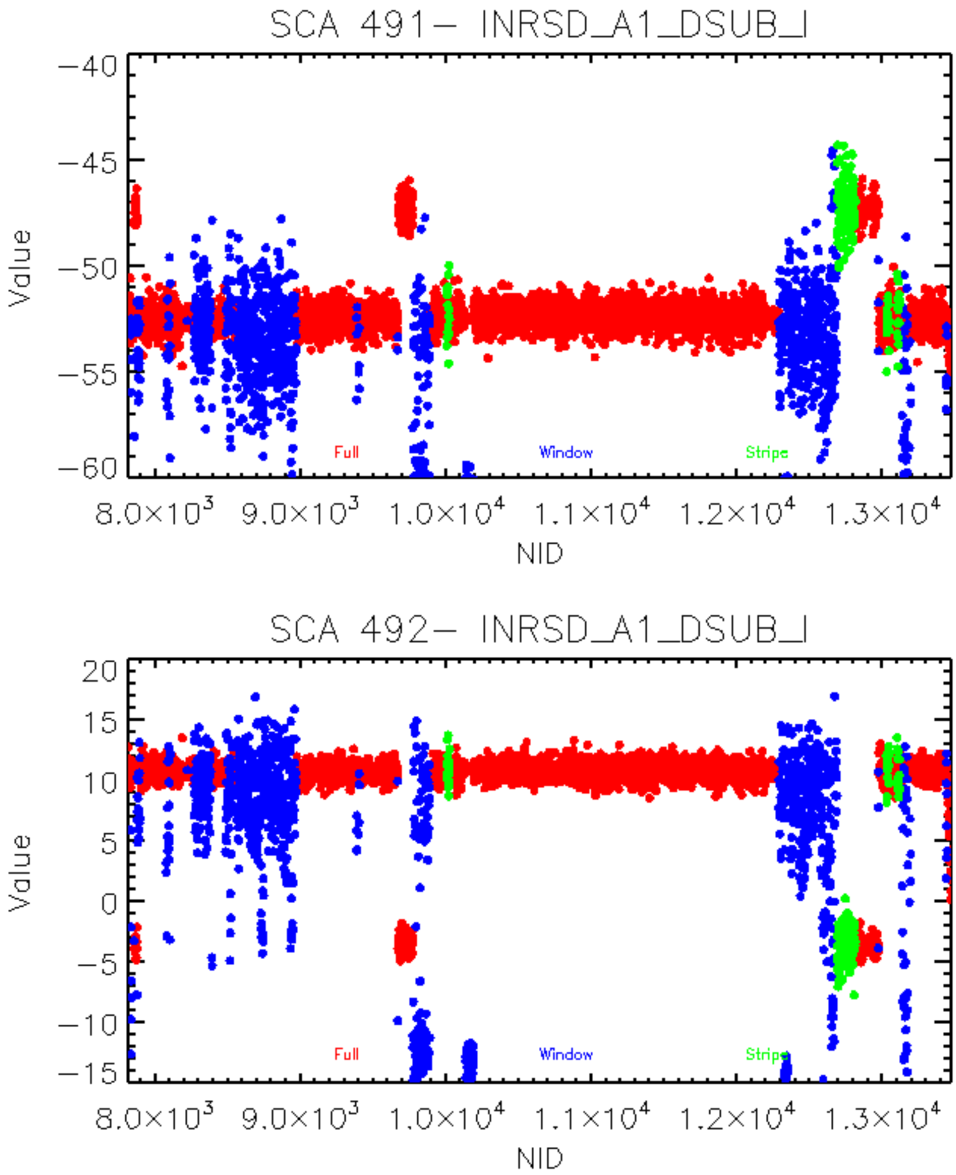

Figure 8 DSUB bias current telemetry reading during FM2-A for SCA491 (top) and SCA492(bottom)

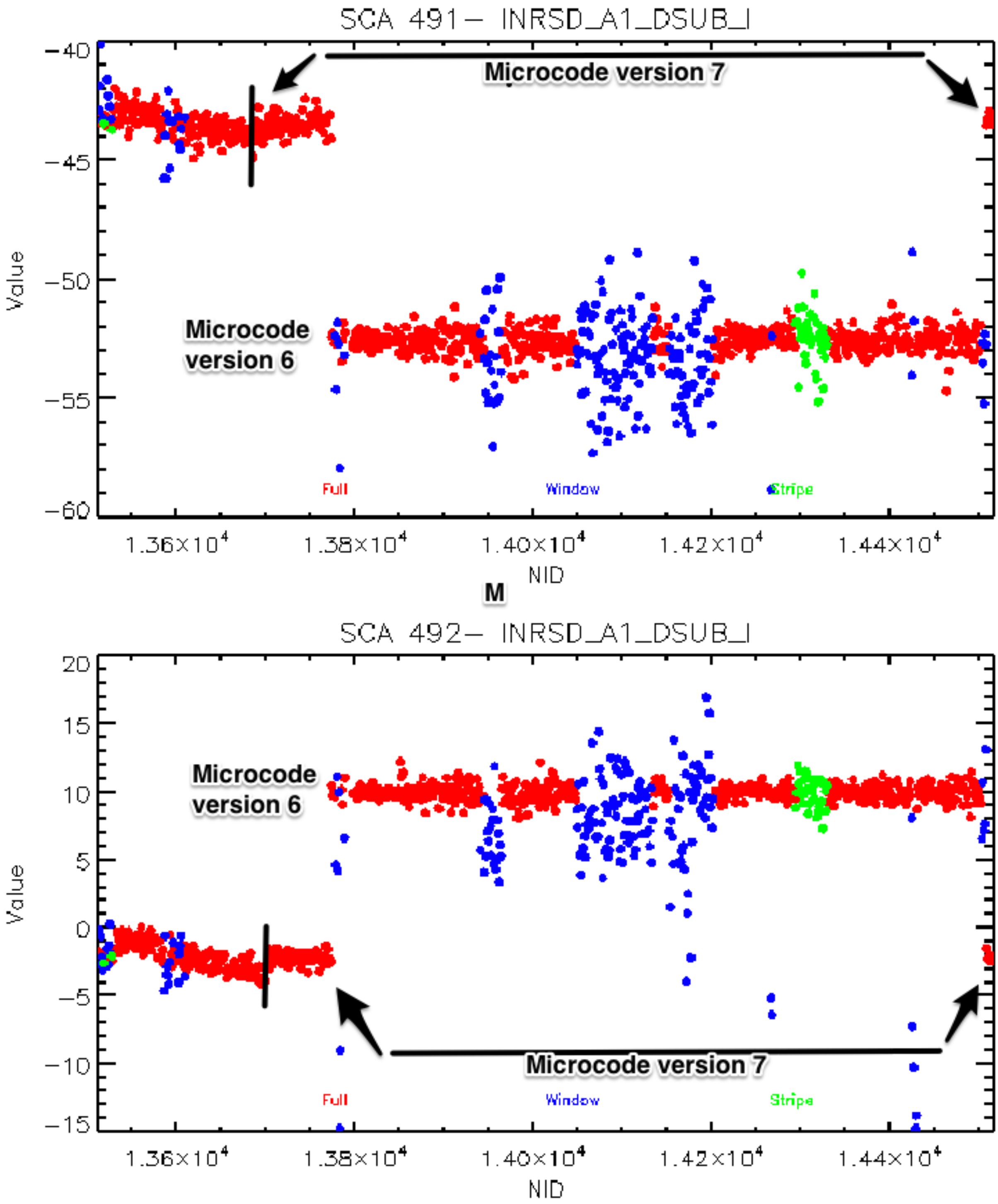

Figure 9 DSUB bias current during FM2B for SCA491 (top) and SCA492 (bottom). Arrows indicate data acquired with microcode version 7. The black vertical line indicates the transition between two different versions of the personality files used for μcode 7 testing (see NTN-2013-015 for details).

5 IMPACT ON SCIENCE AND OPERATIONS

Our current pipeline removes the channel drift by using the reference pixels in each image. The pipeline also subtracts to each ramp a superbias, a high signal to noise zero frame built with many (> 100) dark integrations with just one group of one frame. This superbias has imprinted the channel drift. If the superbias prepared with data in a given DSUB/channel drift state is applied to a set of data with a different state it will not correct properly for the reset level of the pixel. This can introduce additional errors on the linearity correction. During FM2 we have been monitoring the DSUB current and we have repeated critical exposures acquired while the DSUB was in the "anomalous" state. To assess whether the change in DSUB current has an impact on science, we conducted an analysis of individual spectra acquired during the FM2 test campaign. We selected for this analysis two exposures (9679 and 12000) with the same instrument configuration but with different DSUB current state. By studying the ratio between spectra of these two exposures we can detect any change in the flux levels that could be caused by the fact that the super bias frame used in the reductions is not representative of the detector state. The use of the MSA allows us to study spectra located at each of the four detector outputs. To validate our results, we repeated the test on two other exposures where the DSUB biases remained stable (8451 and 11932). Table 3 summarizes the instrument configuration parameters for the four exposures.

Table 3. Exposures used for the spectral analysis

NID	Date Obs	Filter	Grating	Lamp	DSUB anomaly
9679	20-03-2013	F100LP	G140H	CLS/FF1	Yes
12000	01-03-2013	F100LP	G140H	CLS/FF1	No
8451	27-02-2013	Opaque	G140H	CAA/Flat1	No
11932	01-03-2013	Opaque	G140H	CAA/Flat1	No

We extracted 16 spectra for each exposure using the NIRSpec IPS Pipeline Software. As a first step in the extraction, we applied a correction for the detector Quantum Efficiency variation at pixel level using the detector radiometric response data cubes for each SCA, that were generated using data collected at DCL. Afterwards, each 2D spectrum was rectified to regular coordinates and collapsed into a 1D spectrum.

Figure 9 shows an example of the resulting spectral ratio for the two pairs of exposures, for 4 different shutters located at different detector outputs. The left panel shows the results for the ratio between 9679 and 12000, where 9679 was acquired with the DSUB bias in an anomalous state. For the instrument configuration of these exposures, the signal-to-noise decreases considerably below ~1.2 µm, and therefore the spectral ratio is only studied at longer wavelengths. The right panel shows the ratio between 8451 and 11932, two exposures taken in the nominal DSUB state.
In both test cases, the flux ratio does not show any systematic effect regardless of the change in DSUB status. All four quadrants show very similar results. The same result is

seen in the analysis of the spectra from other micro-shutters. We therefore conclude that the impact of the DSUB instability on science data is minimum.

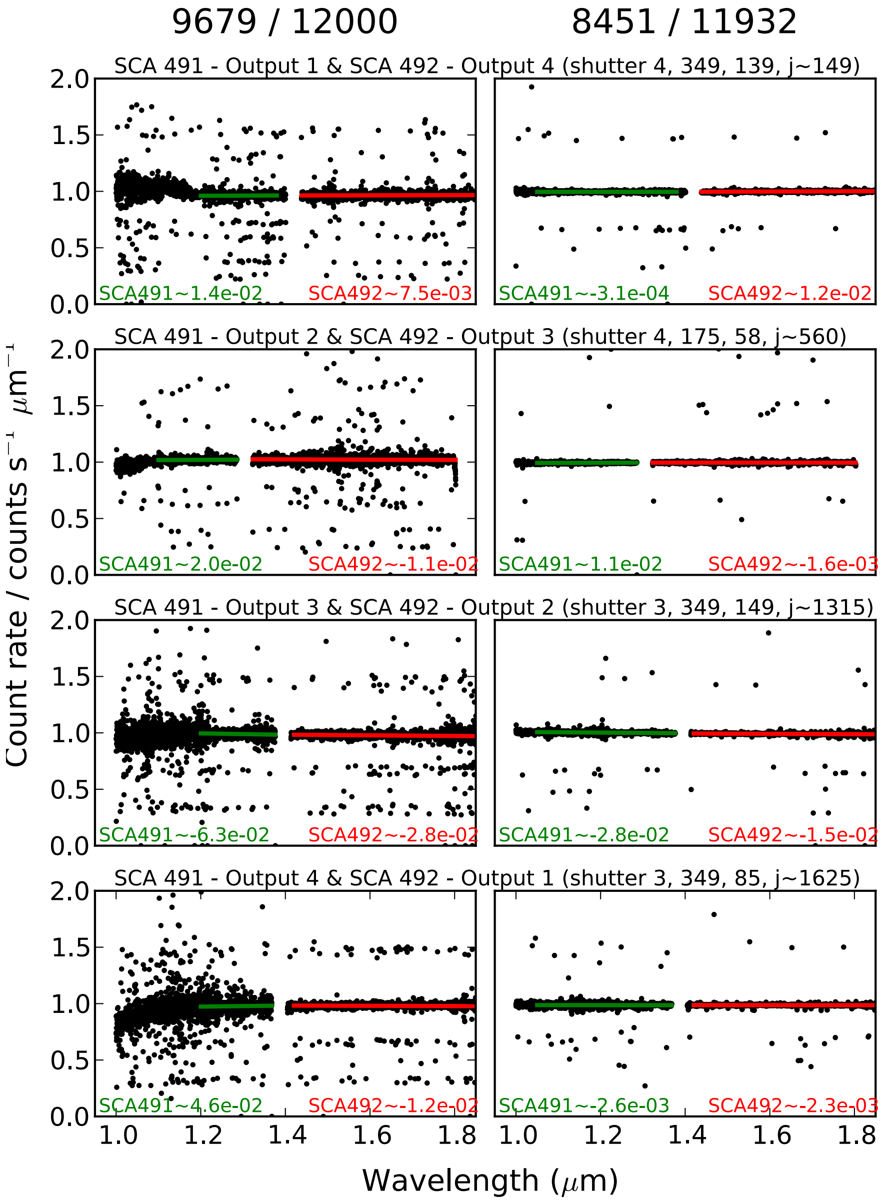

Figure 10. Ration between four micro-shutter spectra from exposures 9679/12000 (left panel) and 8451/11932 (right panels).

6 CONCLUSION

We presented an analysis on the change in the channel drift and the associated correlation with the DSUB current telemetry reading. These are the main findings:

- The value of the DSUB current depends on the ASIC microcode version
- Jumps in the DSUB current can occur only when switching to/from a window mode exposure.
- The impact of the DSUB current instability on science data is minimal, however it should be assessed whether the dual state of the channel drift is an indication of any anomaly that could degrade even further and put at risk the hardware functionality.
- In updated versions of the ASIC FAC (build >6) the retrieval of accurate telemetry reading will be possible and it would facilitate the understanding of what initiate the change in DSUB current.
- Since this change in channel drift is not seen in DCL data taken during the FPA104 characterization, an accurate analysis of the difference of the set up during the two tests should be carried out. It is worth to remember that the flight model FPE was also used for FPA104 characterization.
- The same FPA and pair of ASICs will be used during ISIM CV2. This anomaly does not impact the primary goal of ISIM CV2 which is to verify the integrity of the instrument after shipping and installation into ISIM.
- The new FPA106 will be characterized with a different pair of ASICs at DCL and installed in NIRSpec after CV2. If the anomaly is not related to the specific ASIC or SCAs it is possible that the anomaly will show up in data acquired during CV3. If this happens more data will be needed during ISIM CV3 for the creation of reference files.

7 REFERENCES

[1] NTN-2013-015 Analysis in support to NCR 1602. ASIC μcode 7 trobleshooting – M Sirianni, 2013 - ESA.